

Claims

What is claimed is:

1. An apparatus for radially expanding and plastically deforming a tubular member, comprising:
 - a support member; and
 - an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the tubular member, comprising:
 - a support structure coupled to the support member;
 - one or more expansion device segments for engaging the tubular member to thereby radially expand and plastically deform the tubular member;
 - one or more adjustable spring elements coupled between the support structure and one or more of the expansion device segments;
 - one or more adjustable damping elements coupled between the support structure and one or more of the expansion device segments; and
 - one or more sensors for sensing operating conditions during the radial expansion and plastic deformation of the tubular member by the adaptive expansion device;
 - a controller operably coupled to the adjustable spring elements, the adjustable damping elements, and the sensors; and
 - a user interface operably coupled to the controller for receiving user inputs; wherein the controller is programmed to controllably adjust a spring rate of one or more of the adjustable spring elements, and a damping rate of one or more of the damping elements as a function of the operating conditions sensed by the sensors and the user inputs.
2. A method of adaptively radially expanding a tubular member within a wellbore, comprising:
 - inserting an adaptive expansion device into the tubular member;
 - radially expanding and plastically deforming the tubular member using the adaptive expansion device;
 - sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
 - as a function of the sensed operating conditions, controllably adjusting a spring rate and a damping rate of the adaptive expansion device during the radial expansion and plastic deformation of the tubular member.
3. A system for adaptively radially expanding a tubular member within a wellbore, comprising:
 - means for inserting an adaptive expansion device into the tubular member;

means for radially expanding and plastically deforming the tubular member using the adaptive expansion device;

means for sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and

means for, as a function of the sensed operating conditions, controllably adjusting a spring rate and a damping rate of the adaptive expansion device during the radial expansion and plastic deformation of the tubular member.

4. An apparatus for radially expanding and plastically deforming a tubular member, comprising:
- a support member; and
 - an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the tubular member, comprising:
 - a support structure coupled to the support member;
 - one or more expansion device segments for engaging the tubular member to thereby radially expand and plastically deform the tubular member; and
 - one or more sensors for sensing operating conditions during the radial expansion and plastic deformation of the tubular member by the adaptive expansion device; and
 - a controller operably coupled to the expansion device segments and the sensors; wherein the controller is programmed to controllably adjust a frequency characteristic of one or more of the expansion device segments as a function of the operating conditions sensed by the sensors.

5. A method of adaptively radially expanding a tubular member within a wellbore, comprising:
- inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular member into the tubular member;
 - radially expanding and plastically deforming the tubular member using the adaptive expansion device;
 - sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
 - as a function of the sensed operating conditions, controllably adjusting a frequency response characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the tubular member.

6. A system for adaptively radially expanding a tubular member within a wellbore, comprising:
- means for inserting an adaptive expansion device comprising one or more expansion

device segments for engaging and radially expanding and plastically deforming the tubular member into the tubular member;
means for radially expanding and plastically deforming the tubular member using the adaptive expansion device;
means for sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
means for, as a function of the sensed operating conditions, controllably adjusting a frequency response characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the tubular member.

7. An apparatus for radially expanding and plastically deforming overlapping ends of first and second tubular members, comprising:
a support member; and
an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the overlapping ends of the tubular members, comprising:
a support structure coupled to the support member;
one or more expansion device segments for engaging the overlapping ends of the tubular members to thereby radially expand and plastically deform the overlapping ends of the tubular member; and
one or more sensors for sensing operating conditions during the radial expansion and plastic deformation of the overlapping ends of the tubular member by the adaptive expansion device; and
a controller operably coupled to the expansion device segments and the sensors; wherein the controller is programmed to controllably adjust one or more operational characteristics of one or more of the expansion device segments as a function of a sensing of the overlapping ends of the tubular members by one or more of the sensors.

8. A method of adaptively radially expanding overlapping ends of tubular members within a wellbore, comprising:
inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular member into the overlapping ends of the tubular members;
radially expanding and plastically deforming the overlapping ends of the tubular members using the adaptive expansion device;
sensing the overlapping ends of the tubular members during the radial expansion and plastic deformation of the overlapping ends of the tubular members; and

as a function of the sensing of the overlapping ends of the tubular members, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the overlapping ends of the tubular members.

9. A system for adaptively radially expanding overlapping ends of tubular members within a wellbore, comprising:
- means for inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular member into the overlapping ends of the tubular members;
 - means for radially expanding and plastically deforming the overlapping ends of the tubular members using the adaptive expansion device;
 - means for sensing the overlapping ends of the tubular members during the radial expansion and plastic deformation of the overlapping ends of the tubular members; and
 - means for, as a function of the sensing of the overlapping ends of the tubular members, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the overlapping ends of the tubular members.
10. An apparatus for radially expanding and plastically deforming first and second tubular members coupled to one another by a threaded connection, comprising:
- a support member; and
 - an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the threaded connection, comprising:
 - a support structure coupled to the support member;
 - one or more expansion device segments for engaging the threaded connection to thereby radially expand and plastically deform the threaded connection; and
 - one or more sensors for sensing operating conditions during the radial expansion and plastic deformation of the threaded connection by the adaptive expansion device; and
 - a controller operably coupled to the expansion device segments and the sensors; wherein the controller is programmed to controllably adjust one or more operational characteristics of one or more of the expansion device segments as a function of a sensing of the threaded connection by one or more of the sensors.
11. A method of adaptively radially expanding tubular members coupled to one another by a threaded connection within a wellbore, comprising:

inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular members proximate the threaded connection;
radially expanding and plastically deforming the threaded connection using the adaptive expansion device;
sensing the threaded connection during the radial expansion and plastic deformation of the threaded connection; and
as a function of the sensing of the threaded connection, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the threaded connection.

12. A system for adaptively radially expanding tubular members coupled to one another by a threaded connection within a wellbore, comprising:
means for inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular members proximate the threaded connection;
means for radially expanding and plastically deforming the threaded connection using the adaptive expansion device;
means for sensing the threaded connection during the radial expansion and plastic deformation of the threaded connection; and
means for, as a function of the sensing of the threaded connection, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the threaded connection.

13. An apparatus for radially expanding and plastically deforming a tubular member within a wellbore that traverses a subterranean formation, comprising:
a support member; and
an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the tubular member and elastically deforming the subterranean formation, comprising:
a support structure coupled to the support member;
one or more expansion device segments for engaging the threaded connection to thereby radially expand and plastically deform the tubular member and elastically deform the subterranean formation; and
one or more sensors for sensing operating conditions during the radial expansion and plastic deformation of the tubular member and the elastic deformation of the subterranean formation; and

a controller operably coupled to the expansion device segments and the sensors; wherein the controller is programmed to controllably adjust one or more operational characteristics of one or more of the expansion device segments as a function of a sensing of the subterranean formation by one or more of the sensors.

14. A method of adaptively radially expanding a tubular member within a wellbore that traverses a subterranean formation, comprising:

inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular member and elastically deforming the subterranean formation within the wellbore;

radially expanding and plastically deforming the tubular member and elastically deforming the subterranean formation using the adaptive expansion device; sensing the subterranean formation during the radial expansion and plastic deformation of the tubular member and the elastic deformation of the subterranean formation; and

as a function of the sensing of the subterranean formation, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the tubular member and the elastic deformation of the subterranean formation.

15. A system for adaptively radially expanding a tubular member within a wellbore that traverses a subterranean formation, comprising:

means for inserting an adaptive expansion device comprising one or more expansion device segments for engaging and radially expanding and plastically deforming the tubular member and elastically deforming the subterranean formation within the wellbore;

means for radially expanding and plastically deforming the tubular member and elastically deforming the subterranean formation using the adaptive expansion device;

means for sensing the subterranean formation during the radial expansion and plastic deformation of the tubular member and the elastic deformation of the subterranean formation; and

means for, as a function of the sensing of the subterranean formation, controllably adjusting an operational characteristic of one or more of the expansion device segments during the radial expansion and plastic deformation of the tubular member and the elastic deformation of the subterranean formation.

16. An apparatus for radially expanding and plastically deforming a tubular

member, comprising:

- a support member; and
 - an adaptive expansion device coupled to the support member for radially expanding and plastically deforming the tubular member, comprising:
 - a support structure coupled to the support member; and
 - one or more expansion device segments coupled to the support structure for engaging the tubular member to thereby radially expand and plastically deform the tubular member;
 - one or more sensors for sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
 - a controller operably coupled to the expansion device segments and the sensors; and
- wherein the controller is programmed to controllably adjust one or more of the operational characteristics of one or more the expansion device segments as a function of the operating conditions sensed by the sensors.

17. A method of adaptively radially expanding a tubular member within a wellbore, comprising:

- inserting an adaptive expansion device into the tubular member;
- radially expanding and plastically deforming the tubular member using the adaptive expansion device;
- sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
- as a function of the sensed operating conditions, controllably adjusting one or more of the operating characteristics of the adaptive expansion device during the radial expansion and plastic deformation of the tubular member.

18. A system for adaptively radially expanding a tubular member within a wellbore, comprising:

- means for inserting an adaptive expansion device into the tubular member;
- means for radially expanding and plastically deforming the tubular member using the adaptive expansion device;
- means for sensing one or more operating conditions during the radial expansion and plastic deformation of the tubular member; and
- means for, as a function of the sensed operating conditions, controllably adjusting one or more of the operating characteristics of the adaptive expansion device during the radial expansion and plastic deformation of the tubular member.

19. The apparatus of claims 1, 4, 7, 10, 13, or 16, wherein one or more of the expansion device segments comprise:

one or more expansion surfaces; and
an actuator coupled to the expansion surfaces.

20. The apparatus of claim 19, wherein the actuator comprises one or more degrees of freedom.

21. The apparatus of claim 20, wherein the actuator comprises a plurality of degrees of freedom.

22. The apparatus of claim 19, wherein the actuator comprises one or more rotary actuators.

23. The apparatus of claims 1, 4, 7, 10, 13, or 16, wherein one or more of the expansion device segments comprise:

one or more hydro-forming devices.

24. The method of claims 2, 5, 8, 11, 14, or 17, wherein radially expanding and plastically deforming the tubular member using the adaptive expansion device comprises: displacing the adaptive expansion device relative to the tubular member in the longitudinal direction.

25. The method of claims 2, 5, 8, 11, 14, or 17, wherein radially expanding and plastically deforming the tubular member using the adaptive expansion device comprises: rotating the adaptive expansion device relative to the tubular member.

26. The method of claims 2, 5, 8, 11, 14, or 17, wherein radially expanding and plastically deforming the tubular member using the adaptive expansion device comprises: applying a pressurized fluid to the interior surface of the tubular member.

27. The system of claims 3, 6, 9, 12, 15, or 18, wherein the means for radially expanding and plastically deforming the tubular member using the adaptive expansion device comprises:

means for displacing the adaptive expansion device.

28. The system of claim 27, wherein the means for displacing the adaptive expansion device comprises one or more degrees of freedom.

29. The system of claim 27, wherein the means for displacing the adaptive expansion device comprises a plurality of degrees of freedom.

30. The system of claims 3, 6, 9, 12, 15, or 18, wherein the means for radially expanding and plastically deforming the tubular member using the adaptive expansion device comprises:

means for radially expanding and plastically deforming the tubular member using a hydro-forming device.